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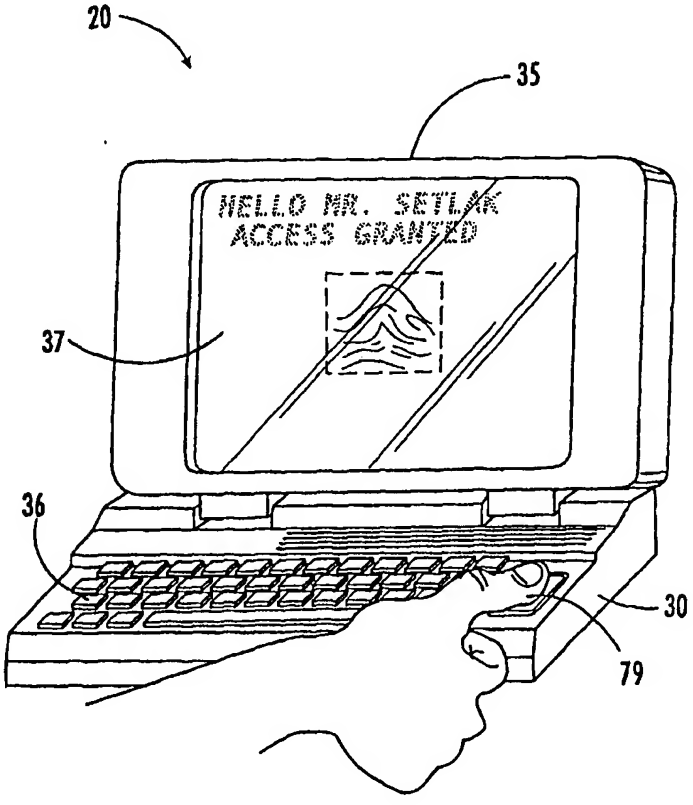
(54) Title: METHOD AND APPARATUS FOR CREATING A COMPOSITE FINGERPRINT IMAGE

(57) Abstract

A method and apparatus generates fingerprint data for a fingerprint area larger than a sensing area of a fingerprint sensor. A fingerprint of a user is enrolled by generating fingerprint data sets responsive to placing a finger of a user on a sensing area of the fingerprint sensor a plurality of times with the finger being slightly repositioned on successive placements. The method also includes processing the fingerprint data sets to generate a composite fingerprint data set over an area of the fingerprint larger than the sensing area of the fingerprint sensor. The method may also be extended to the matching of a new fingerprint to an enrolled fingerprint based upon at least one sensing of the new fingerprint and the composite fingerprint data sets. A plurality of fingerprint feature location data sets may be generated and include at least one of a plurality of minutiae location data sets, a plurality of skin pore location data sets, and a plurality of feature location data sets relating to fingerprint ridge flows.



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METHOD AND APPARATUS FOR CREATING A COMPOSITE FINGERPRINT IMAGE

Related Application

This application is based upon prior filed copending provisional application Serial No. 60/133,414 filed May 11, 1999.

Field of the Invention

The invention relates to the field of fingerprint processing, and, more particularly, to the field of storing a database of fingerprint data and matching a new fingerprint to the database.

Background of the Invention

Fingerprint matching is a reliable and widely used technique for personal identification or verification. In particular, a common approach to fingerprint identification involves scanning a sample fingerprint or an image thereof, converting it into electrical signals, and storing the image and/or unique characteristics of the fingerprint image. The characteristics of a sample or new fingerprint may be compared to information for reference fingerprints already in storage to determine or verify a person's identity.

Unfortunately, comparing a sample fingerprint to a large number of reference fingerprints may be prohibitively expensive and/or simply take too long.

Accordingly, fingerprints are typically classified into a plurality of discrete sets and/or subsets in the form of a hierarchical tree to thereby expedite searching. For example, a common top level classification for fingerprints usually differentiates the prints into the classes of: plain whorl, plain loop, tented arch, etc. based upon broad ridge pattern types. These classes may be yet further divided into subclasses. Accordingly, a fingerprint sample to be searched, once itself classified, can be more efficiently compared to only those prints in the respective classes and subclasses of the search tree. For example, U.S. Patent No. 5,465,303 to Levison et al. describes both the widely used Henry classification system and the Vucetich classification system.

When the quality of the original copy of a fingerprint is bad, the print may contain many local distortions of the ridge pattern which may result in incorrect orientation of the fingerprint. U.S. Patent No. 5,140,642 to Hsu et al. is directed to a method for determining the actual position of a core point of a fingerprint based upon finding ridge flows and assigning a direction code, correcting the ridge flows, and allocating the core point based upon the corrected direction codes. Along these lines, U.S. Patent No. 5,040,224 to Hara discloses an approach to preprocessing fingerprints to correctly determine a position of the core of each fingerprint image for later matching by minutiae patterns.

Fingerprint minutiae, the branches or bifurcations and end points of the fingerprint ridges, are often used to determine a match between a sample print and a reference print database. For example, U.S. Patent Nos. 3,859,633 and 3,893,080 both to Ho et

al. are directed to fingerprint identification based upon fingerprint minutiae matching.

U.S. Patent No. 4,151,512 to Riganati et al. describes a fingerprint classification method using extracted ridge contour data. The ridge flow in the fingerprint pattern and minutiae data are identified and extracted from a fingerprint pattern. Topological data, identifying singularity points such as tri-radii and cores, as well as ridge flow line tracings related to those points are extracted from the ridge contour data. The extracted information is used to automatically perform classification of the fingerprint patterns and/or matching of the fingerprint pattern with patterns stored in a mass file.

U.S. Patent No. 5,845,005 to Setlak et al., and assigned to the assignee of the present invention, discloses a significant advance in the area of fingerprint indexing and searching of a database of reference fingerprints to determine a match. In particular, index values are calculated which are generally evenly distributed and continuous over a relatively large population of individuals. The index values may be determined based upon ridge flow curvature of the fingerprints. A particularly advantageous index, called a curliness index, is disclosed and this index is based upon an aggregate of a magnitude of a rate of change of ridge direction vectors.

Other important advances have also been made in the area of integrated circuit fingerprint sensors, as disclosed, for example, in U.S. Patent Nos. 5,828,773 and 5,862,248, both assigned to the assignee of the present invention. The disclosed sensors are based upon generating an electric field which can sense the ridges of a fingerprint despite contamination, skin

surface damage, and other factors. The sensor is relatively compact and rugged.

Despite improvements in sensor technology and in fingerprint enrollment and matching approaches, processing is still computationally intensive thus limiting widespread use of fingerprint sensing. In addition, sensing typically requires a relatively large sensor area to ensure accurate results. The sensor size has an important bearing on the sensor cost, especially for the new class of integrated circuit fingerprint sensors.

Summary of the Invention

In view of the foregoing background, it is therefore an object of the invention to provide a method and fingerprint sensor apparatus for enrolling and/or matching a fingerprint, and to reduce computations and/or permit the sensing surface to be relatively small.

This and other objects, features and advantages in accordance with the present invention are provided in one embodiment by a method for generating fingerprint data for a fingerprint area larger than a sensing area of a fingerprint sensor. The method preferably comprises enrolling a fingerprint of a user by generating a plurality of fingerprint data sets responsive to placing a finger of a user on a sensing area of the fingerprint sensor a plurality of times with the finger being slightly repositioned on successive placements. The method also preferably includes processing the plurality of fingerprint data sets to generate a composite fingerprint data set over an area of the fingerprint larger than the sensing area of the fingerprint sensor. Of course, the method may also be extended to the matching of a new fingerprint to an enrolled fingerprint based upon at least one

sensing of the new fingerprint and the composite fingerprint data set.

The step of matching may include comparing a predetermined number of sensings of the new fingerprint with the composite fingerprint data set to achieve a desired performance, such as a desired false reject rate, and/or a desired false acceptance rate. The step of generating a plurality of data sets preferably comprises generating a plurality of fingerprint feature location data sets. The feature location data sets may comprise at least one of a plurality of minutiae location data sets, a plurality of skin pore location data sets, and a plurality of feature location data sets relating to fingerprint ridge flows.

The step of processing may comprise determining a core location for each data set. In addition, the step of processing may comprise accounting for distortion of the finger surface in the plurality of data sets. For example, the step of accounting for distortion preferably comprises calculating centroids of fingerprint feature locations relative to a reference frame or location, such as the fingerprint core position.

The step of generating the plurality of fingerprint data sets may preferably comprise generating a predetermined number of fingerprint data sets based upon the predetermined number of finger placements within a predetermined time. For example, the predetermined number may be in a range of about 2 to 5.

Another aspect of the invention relates to the fingerprint sensor apparatus. The fingerprint sensor apparatus preferably includes a fingerprint sensing area, and an enrollment circuit for enrolling a fingerprint of a user by generating a plurality of

fingerprint data sets responsive to placing a finger of a user on the fingerprint sensing area a plurality of times with the finger being slightly repositioned on successive placements. The enrollment circuit also preferably processes the plurality of fingerprint data sets to generate a composite fingerprint data set over an area of the fingerprint larger than the fingerprint sensing area.

The processor preferably further comprises a match determining circuit for determining a match between a new fingerprint and an enrolled fingerprint based upon at least one sensing of the new fingerprint and the composite fingerprint data sets. The match determining circuit may include a comparor to compare a predetermined number of sensings of the new fingerprint with the composite fingerprint data set to achieve a desired performance, such as a at least one of a false reject rate and a desired false acceptance rate.

The enrollment circuit preferably generates a plurality of fingerprint feature location data sets. The feature location data sets may be minutiae location data sets, skin pore location data sets, and/or feature location data sets relating to fingerprint ridge flows.

The enrollment circuit preferably determines a core location for each data set, and accounts for distortion of the finger surface in the plurality of data sets. The circuit may account for distortion by calculating centroids of fingerprint feature locations relative to a reference frame or location, such as the fingerprint core.

Brief Description of the Drawings

FIG. 1 is a perspective view of a laptop computer including a fingerprint sensor and associated processing software to define an embodiment of the

fingerprint sensing apparatus in accordance with the present invention.

FIG. 2 is a schematic block diagram of the fingerprint sensing apparatus in accordance with the present invention.

FIG. 3 is a flow chart of a method for generating composite data sets in accordance with the present invention.

FIG. 4 is a flow chart of a method for comparing a new fingerprint to composite data sets to determine a match in accordance with the present invention.

FIGS. 5 through 8 are fingerprint images for a plurality of finger placements in accordance with the present invention.

FIG. 9 is a composite/matching image determined from the minutiae of the fingerprint images of FIGS. 5-8 overlaid on a new fingerprint image and feature location data set in accordance with the present invention.

Detailed Description of the Preferred Embodiments

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

Referring initially to FIGS. 1 and 2, the general components and features of the fingerprint sensing apparatus **20** of the present invention are now

described. As shown in FIG. 1, the apparatus **20** in one embodiment includes a fingerprint sensor **30** mounted on the keyboard surface **36** of a laptop computer **35**. The laptop computer **35** also illustratively includes a foldable display **37**. Processing of fingerprint image data may be shared between processing circuitry on the fingerprint sensor **30** and the microprocessor of the computer as would be readily understood by those skilled in the art.

The invention may permit a properly authorized person to become enrolled into a security or access control procedure for the computer **35**. One or more persons may be enrolled as will be described below. To use the computer **35** or to have access to certain files, the user's finger **79** is placed onto the fingerprint sensor **30** and a match is determined with respect to the enrolled authorized persons. If a match is not determined, then access to operate the computer **35** or access to certain files is denied as will be readily appreciated by those skilled in the art. Of course, if a match is determined, the person may be greeted by a visual or audible announcement, and access is granted.

The fingerprint sensor **30** may preferably be of a type that uses electric field sensing of the ridges and valleys of a live fingerprint. Moreover the fingerprint sensor is desirably relatively compact, especially for the application in combination with a laptop computer **35**. For example, the fingerprint sensor **30** may an integrated circuit electric field sensor as offered by AuthenTec, the assignee of the present invention. Various features and attributes of suitable fingerprint sensors are described in U.S. Patent Nos. 5,828,773; 5,862,248; and 5,940,526 and

U.S. patent application attorney work docket no. 51508, filed concurrently herewith, entitled "Fingerprint Sensor With Leadframe Bent Pin Conductive Path and Associated Methods", all assigned to the assignee of the present invention. The subject matter of each of these patents and patent application is incorporated herein by reference in its entirety.

Those of skill in the art will recognize that the apparatus **20** in accordance with the present invention can be implemented in a number of forms in addition to incorporation into the illustrated laptop computer **35** of FIG. 1. For example, the processing circuitry may be incorporated into the integrated circuit of the fingerprint sensor **30**, or may be included in associated circuitry within an overall fingerprints sensor package.

Referring more particularly to FIG. 2, the illustrated apparatus **20** includes an enrollment circuit **21** and a match determining circuit **22**. In some embodiments, either of these circuits may operate without the other; however, the composite data sets database **43** is shared between the two circuits. The circuits **20,22** can be implemented in a microprocessor operating under stored program control as will be readily appreciated by those skilled in the art.

Fingerprint image information from the fingerprint sensor **30** is first processed in the feature location data set generator **40** which generates the data sets for a predetermined number of finger placements, with each placement being slightly offset from the prior placement. As will be readily understood by those skilled in the art, the variation in placement may occur naturally, or may be guided, for example, by indicators on the computer **35**. Such finger positioning

guidance indication is further described in U.S. Patent No. 5,828,773 and needs no further discussion herein.

The feature location data sets may be based upon fingerprint minutiae, fingerprint pores, or fingerprint ridge flows. Fingerprint minutiae and pore location are highly developed as will be appreciated by those skilled in the art. Fingerprint ridge flow analysis and related indexes are described in U.S. Patent No. 5,845,005, for example. Other data sets are also contemplated by the invention as will be appreciated by those skilled in the art.

The number of data sets to enroll a finger may vary depending upon the particular application. For many applications, the number of finger placements and corresponding number of data sets may be about 2 to 5. The number is preferably convenient for the user, but which provides the advantages of the present invention. The data set for each finger placement is generated over a first area, typically defined by the fingerprint sensing area.

Downstream from the feature location data sets generator **40** is a filter and skin distortion processing block **41**. The filter and skin distortion processing block **41** may remove undesired weak features or artifact features from processing. In addition, the processing block **41** may determine the location of the fingerprint features relative to a predetermined frame of reference, such as based upon the fingerprint core. Determination of the fingerprint core will be readily understood by those skilled in the art without requiring further discussion herein.

A centroid, for example, may be calculated for each similar feature in different data sets. Of course, skin distortion will cause those features further from the core to appear to have a greater

spacing. Thus the determination of what is the same feature on different placements is determined based upon the distance from the core, for example. Those skilled in the art will recognize other similar processing that can be performed to ensure that successive data sets can be correlated one to the other(s).

In particular, downstream from the filter and distortion processing block **41**, is located the composite data set generator **42**. As will be appreciated by those skilled in the art, because multiple finger placements at slightly different positions are processed, the composite data set can correspond to a larger area than the first area for each finger sensing. This first area typically being limited by the size of the sensing area of the fingerprint sensor **30**. In other words, the second area of the composite data set is larger than any of the individual fingerprint sensings of the finger during enrollment. Accordingly, two significant advantages are available. First, the size of the sensing area of the fingerprint sensor **30** can be reduced. For an integrated circuit embodiment of the fingerprint sensor **30**, substantial savings can be realized by reducing the needed sensing area.

Second, the positioning of the finger to be matched may be relaxed. In other words, since the new fingerprint feature set is compared to a larger composite data set, positioning of the finger is not as critical. Both of these noted advantages of the invention can be realized, or trade-offs can be made. In addition, reductions can also be realized in the calculations required.

Referring now more particularly to the lower portion of FIG. 2, the match determining circuit **22** is further described. This circuit **22** is shown connected to the same fingerprint sensor **30**, as will typically be the case. However, in other embodiments, a different fingerprint sensor, and perhaps having a different sensing area, may also be used.

The fingerprint sensor **30** is connected to the new fingerprint feature location data set generator block **41**. For example, this block **41** may generate a set of minutiae locations, pore locations, or ridge flow related location data, as described above for the enrollment. The data set from the new fingerprint feature location data set generator **41** is input to the comparor **45** which, in turn, is also connected to the composite data sets database **43**. The comparor **45** compares the new fingerprint feature location data set with those already stored to determine if a match exists. The various processing algorithms for determining a match will be readily appreciated by those skilled in the art without requiring further discussion herein.

If a correct match between the new fingerprint and one stored in the database **43** is determined, such may be indicated by the schematically illustrated match indicator **46**. For example, the match indicator **46** may be a message on the display screen **37** of the laptop computer **35**. Alternately or in addition thereto, a match indication may be indicated simply by granting the user access or permission to continue.

Turning now to the flow chart of FIG. 3, the method steps for enrolling a fingerprint of a user are now described in greater detail. From the start (Block **50**) the user positions or places his finger on the

fingerprint sensor **30** at Block **52**. The fingerprint sensor has a first area. A feature location data set is generated at Block **54**. At Block **56** the number of times the finger has been positioned is determined and if the number is not sufficient, that is, less than the desired number N, then the process returns to Block **52**.

If N data sets have been generated as determined at Block **56** then the method proceeds to the filter and accounting for skin distortion at Block **58** as described in greater detail above. The N data sets are preferably collected over a predetermined period of time to ensure that only the desired user is enrolling. In other words, a learning or enrolling window is opened for only a predetermined time to thereby increase security as will be appreciated by those skilled in the art.

At Block **60** a composite data set is stored in a database **43**, and the process stops (Block **62**). Of course, the process may be repeated for a number of users to be enrolled into the database **43** as will be readily appreciated by those skilled in the art.

Turning now additionally to the flow chart of FIG. 4, the method of matching a new fingerprint is described in greater detail. From the start (Block **70**), the finger is positioned on the fingerprint sensor **30** at Block **72**. A new feature location data set is generated at Block **74**. If the finger has been properly positioned and the data is acceptable as determined at Block **76**, the new data set is compared to the composite data sets in the database **43**. If the position or data at Block **76** is not acceptable then the user may reposition his finger **79** and repeat the process. If a match is determined at Block **80**, a match is indicated at Block **98** before the process terminates (Block **98**).

In addition, as would be readily understood by those skilled in the art, the matching may include comparing a predetermined number of sensings of the new fingerprint with the composite fingerprint data sets. The number of matchings may be determined to achieve a desired performance, such as a desired false reject rate, and/or a desired false acceptance rate.

If after comparing the new data set to the data sets in the composite database **43**, a number of retries R is checked at Block **90**, and if the number of retries R is less than a predetermined threshold (Block **92**) the process is repeated. If the number of retries at Block **92** is greater than the threshold a failure is indicated and access may be denied at Block **94**.

Turning now to FIGS. 5-8, a series of fingerprint images for a finger being enrolled are shown. A frame of reference **100** is shown in each of the figures. The frame of reference is based upon the core of the fingerprint, although rotation of the different images is not illustrated but can be readily calculated based upon the location of the fingerprint minutiae. Various minutiae are located in the images as would be readily understood by those skilled in the art. FIGS. 6-8 also include respective labeled areas **A**, **B** and **C** enclosing respective groups of minutiae points.

The labeled areas **A**, **B** and **C** include minutiae points which are illustrated in the composite/matching image of FIG. 9. The composite/matching image shows the location of the minutiae points based upon the successive finger placements (FIGS. 5-8). In addition, the new fingerprint image is superimposed on the minutiae in the figure as will be appreciated by those skilled in

the art. As will also be understood by those skilled in the art, other fingerprint features can also be similarly processed and analyzed.

Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

THAT WHICH IS CLAIMED IS:

1. A method for generating fingerprint data for a fingerprint area larger than a sensing area of a fingerprint sensor, the method comprising:

generating a plurality of fingerprint data sets responsive to placing a finger of a user on the sensing area of the fingerprint sensor a plurality of times with the finger being slightly repositioned on successive placements; and

processing the plurality of fingerprint data sets to generate a composite fingerprint data set over a size of the fingerprint larger than the sensing area of the fingerprint sensor.

2. A method according to Claim 1 wherein generating a plurality of fingerprint data sets comprises generating a plurality of fingerprint feature location data sets.

3. A method according to Claim 2 wherein generating a plurality of fingerprint feature location data sets comprises generating a plurality of minutiae location data sets.

4. A method according to Claim 2 wherein generating a plurality of fingerprint feature location data sets comprises generating a plurality of skin pore location data sets.

5. A method according to Claim 2 wherein generating a plurality of fingerprint feature location data sets comprises generating a plurality of feature location data sets relating to fingerprint ridge flows.

6. A method according to Claim 2 wherein generating a plurality of fingerprint feature location data sets comprises determining the feature locations with respect to a reference frame.

7. A method according to Claim 6 wherein the reference frame is based upon a fingerprint core location.

8. A method according to Claim 1 wherein processing comprises accounting for distortion of the finger surface in the plurality of fingerprint data sets.

9. A method according to Claim 8 wherein generating a plurality of fingerprint data sets comprises generating a plurality of fingerprint feature location data sets; and wherein the step of accounting for distortion comprises calculating centroids of fingerprint feature locations relative to a reference location.

10. A method according to Claim 9 wherein the reference location comprises a fingerprint core location.

11. A method according to Claim 1 wherein generating the plurality of fingerprint data sets comprises generating a predetermined number of fingerprint data sets based upon the predetermined number of finger placements within a predetermined time.

12. A method according to Claim 10 wherein the predetermined number of finger placement comprises a number in a range of about 2 to 5.

13. A method according to Claim 1 wherein the fingerprint sensor comprises a fingerprint sensing integrated circuit.

14. A method for using a fingerprint sensor comprising:

enrolling a fingerprint of a user by generating a plurality of fingerprint data sets responsive to placing a finger of a user on a sensing area of the fingerprint

sensor a plurality of times with the finger being slightly repositioned on successive placements, and

processing the plurality of fingerprint data sets to generate a composite fingerprint data set over an area of the fingerprint larger than the sensing area of the fingerprint sensor; and

matching a new fingerprint to an enrolled fingerprint based upon at least one sensing of the new fingerprint and the composite fingerprint data sets.

15. A method according to Claim 14 wherein matching comprises comparing at least one sensing of the new fingerprint with the composite fingerprint data sets to achieve a desired performance.

16. A method according to Claim 15 wherein the desired performance comprises at least one of a desired false acceptance rate and a desired false reject rate.

17. A method according to Claim 14 wherein generating a plurality of fingerprint feature location data sets comprises generating a plurality of minutiae location data sets.

18. A method according to Claim 14 wherein generating a plurality of fingerprint feature location data sets comprises generating a plurality of skin pore location data sets.

19. A method according to Claim 14 wherein generating a plurality of fingerprint feature location data sets comprises generating a plurality of feature location data sets relating to fingerprint ridge flows.

20. A method according to Claim 14 wherein generating a plurality of fingerprint feature location data sets comprises determining the feature locations with respect to a reference frame.

21. A method according to Claim 20 wherein the reference frame is based upon a fingerprint core location.

22. A method according to Claim 14 wherein processing comprises accounting for distortion of the finger surface in the plurality of fingerprint data sets.

23. A method according to Claim 13 wherein generating a plurality of fingerprint data sets comprises generating a plurality of fingerprint feature location data sets; and wherein the step of accounting for distortion comprises calculating average fingerprint feature locations relative to a reference frame.

24. A method according to Claim 23 wherein the reference frame is based upon a fingerprint core location.

25. A method according to Claim 14 wherein generating the plurality of fingerprint data sets comprises generating a predetermined number of fingerprint data sets based upon the predetermined number of finger placements within a predetermined time.

26. A method according to Claim 25 wherein the predetermined number of finger placement comprises a number in a range of about 2 to 5.

27. A method according to Claim 14 wherein the fingerprint sensor comprises an fingerprint sensing integrated circuit.

28. A fingerprint sensing apparatus comprising:

a fingerprint sensing area; and

an enrollment circuit for enrolling a fingerprint of a user by generating a plurality of fingerprint data sets responsive to placing a finger of

a user on the fingerprint sensing area a plurality of times with the finger being slightly repositioned on successive placements, and processing the plurality of fingerprint data sets to generate a composite fingerprint data set over an area of the fingerprint larger than the fingerprint sensing area.

29. A fingerprint sensing apparatus according to Claim 28 further comprising a match determining circuit for determining a match of a new fingerprint to an enrolled fingerprint based upon at least one sensing of the new fingerprint and the composite fingerprint data sets.

30. A fingerprint sensing apparatus according to Claim 29 wherein said match determining circuit includes a comparor for comparing at least one sensing of the new fingerprint with the composite fingerprint data sets to achieve a desired performance.

A fingerprint sensing apparatus according to Claim 30 wherein the desired performance comprises at least one of a false reject rate and a desired false acceptance rate.

31. A fingerprint sensing apparatus according to Claim 28 wherein the enrollment circuit generates a plurality of fingerprint feature location data sets.

32. A fingerprint sensing apparatus according to Claim 28 wherein the enrollment circuit generates a plurality of minutiae location data sets.

33. A fingerprint sensing apparatus according to Claim 28 wherein the enrollment circuit generates a plurality of skin pore location data sets.

34. A fingerprint sensing apparatus according to Claim 28 wherein the enrollment circuit generates a plurality of feature location data sets relating to fingerprint ridge flows.

35. A fingerprint sensing apparatus according to Claim 28 wherein the enrollment circuit determines a fingerprint core location for each data set.

36. A fingerprint sensing apparatus according to Claim 28 wherein the enrollment circuit includes a filter and distortion processor to account for distortion of the finger surface in the plurality of fingerprint data sets.

37. A fingerprint sensing apparatus according to Claim 37 wherein the filter and distortion circuit accounts for distortion by calculating centroids of fingerprint feature locations relative to a reference frame.

38. A fingerprint sensing apparatus according to Claim 38 wherein the reference frame is based upon a fingerprint core location.

39. A fingerprint sensing apparatus according to Claim 28 wherein the enrollment circuit generates a predetermined number of fingerprint data sets based upon the predetermined number of finger placements within a predetermined time.

40. A fingerprint sensing apparatus comprising:

a fingerprint sensor including a fingerprint sensing area;

an enrollment circuit for enrolling a fingerprint of a user by generating a plurality of fingerprint data sets responsive to placing a finger of a user on the fingerprint sensing area a plurality of times with the finger being slightly repositioned on successive placements, and processing the plurality of fingerprint data sets to generate a composite fingerprint data set over an area of the fingerprint larger than the fingerprint sensing area; and

a match determining circuit for determining a match of a new fingerprint to an enrolled fingerprint based upon at least one sensing of the new fingerprint and the composite fingerprint data sets.

41. A fingerprint sensing apparatus according to Claim 41 wherein said match determining circuit includes a comparor for comparing at least one sensing of the new fingerprint with the composite fingerprint data sets to achieve a desired performance.

42. A fingerprint sensing apparatus according to Claim 42 wherein the desired performance comprises at least one of a false reject rate and a desired false acceptance rate.

43. A fingerprint sensing apparatus according to Claim 41 wherein the enrollment circuit generates a plurality of fingerprint feature location data sets.

44. A fingerprint sensing apparatus according to Claim 44 wherein the enrollment circuit generates a plurality of minutiae location data sets.

45. A fingerprint sensing apparatus according to Claim 44 wherein the enrollment circuit generates a plurality of skin pore location data sets.

46. A fingerprint sensing apparatus according to Claim 44 wherein the enrollment circuit generates a plurality of feature location data sets relating to fingerprint ridge flows.

47. A fingerprint sensing apparatus according to Claim 41 wherein the enrollment circuit determines a fingerprint core location for each data set.

48. A fingerprint sensing apparatus according to Claim 41 wherein the enrollment circuit includes a filter and distortion processor to account

for distortion of the finger surface in the plurality of fingerprint data sets.

49. A fingerprint sensing apparatus according to Claim 49 wherein the filter and distortion circuit accounts for distortion by calculating centroids of fingerprint feature locations relative to a reference frame.

50. A fingerprint sensing apparatus according to Claim 50 wherein the reference frame is based upon a fingerprint core location.

51. A fingerprint sensing apparatus according to Claim 41 wherein the enrollment circuit generates a predetermined number of fingerprint data sets based upon the predetermined number of finger placements within a predetermined time.

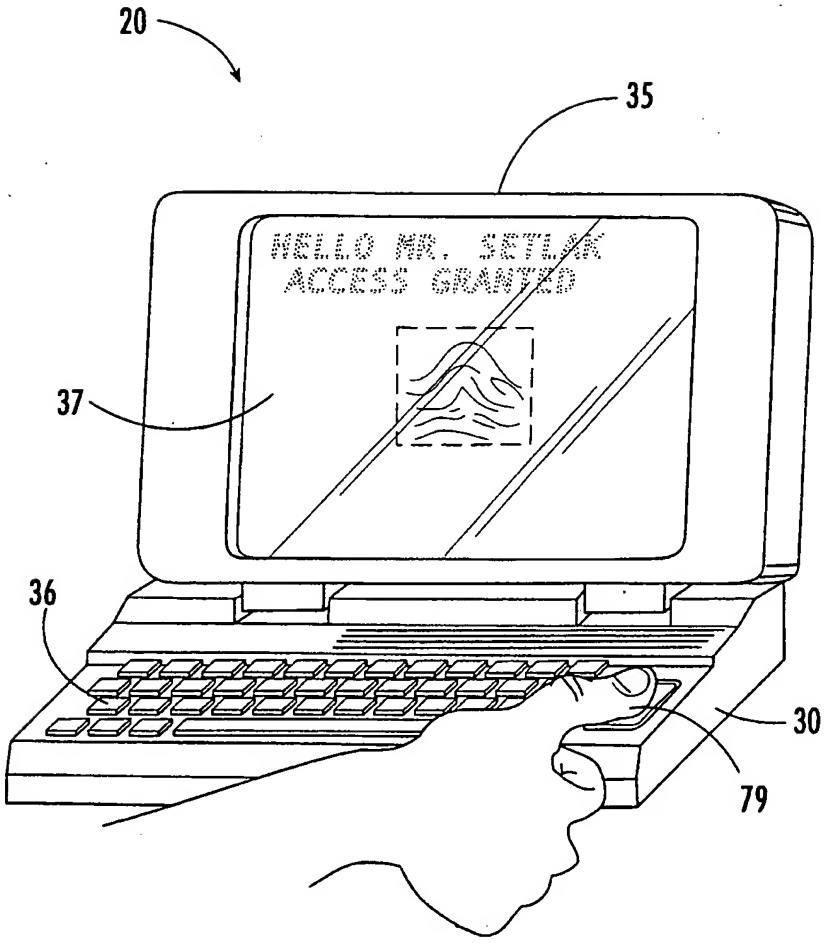

FIG. 1.

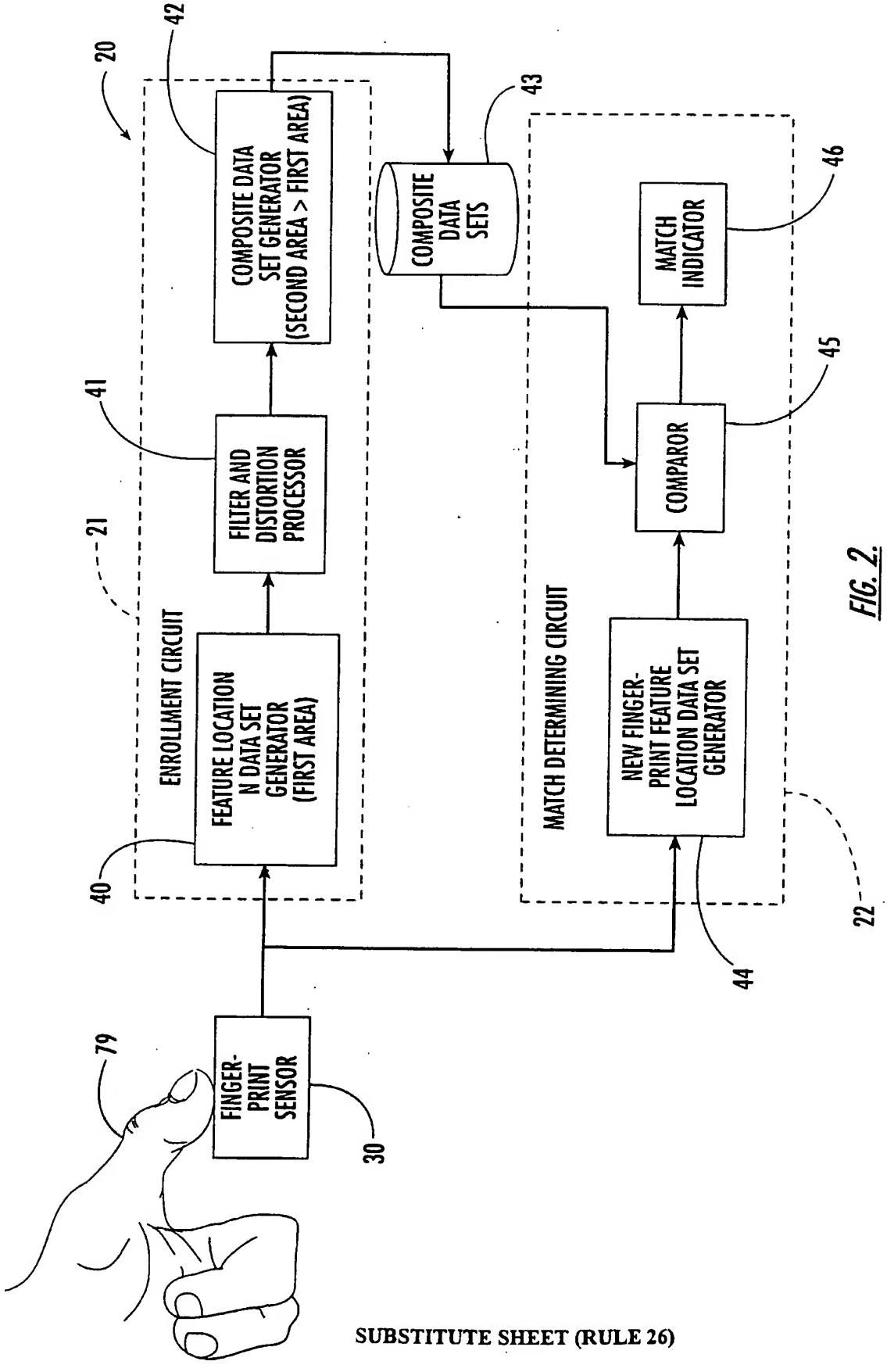
20
42
COMPOSITE DATA SET GENERATOR (SECOND AREA > FIRST AREA)
43
COMPOSITE DATA SETS
46
MATCH INDICATOR
41
FILTER AND DISTORTION PROCESSOR
45
COMPARATOR
21
ENROLLMENT CIRCUIT
MATCH DETERMINING CIRCUIT
FEATURE LOCATION N DATA SET GENERATOR (FIRST AREA)
NEW FINGER-PRINT FEATURE LOCATION DATA SET GENERATOR
40
22
44
79
FINGER-PRINT SENSOR
30

FIG. 2.

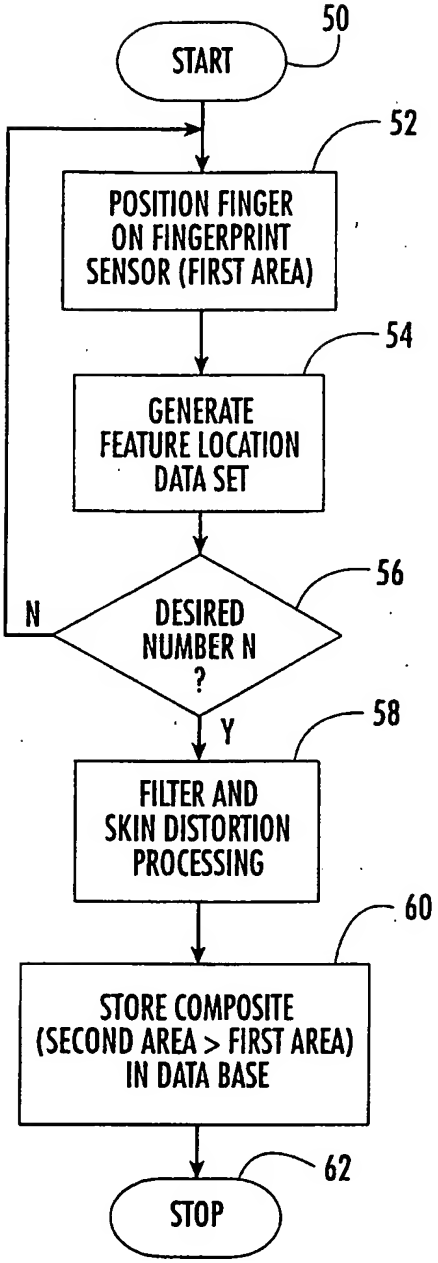
START
50
POSITION FINGER ON FINGERPRINT SENSOR (FIRST AREA)
52
GENERATE FEATURE LOCATION DATA SET
54
DESIRED NUMBER N ?
56
N
Y
FILTER AND SKIN DISTORTION PROCESSING
58
STORE COMPOSITE (SECOND AREA > FIRST AREA) IN DATA BASE
60
STOP
62

FIG. 3.

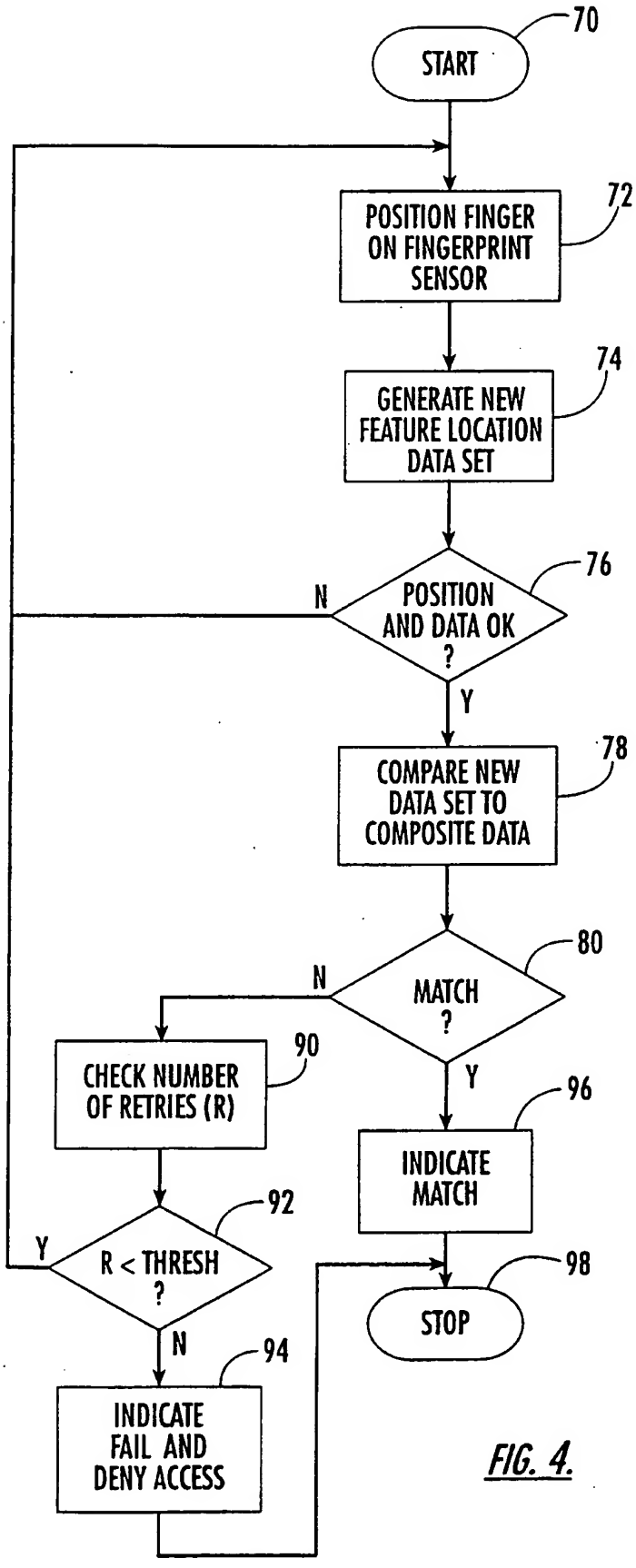
START
70
POSITION FINGER ON FINGERPRINT SENSOR
72
GENERATE NEW FEATURE LOCATION DATA SET
74
POSITION AND DATA OK ?
76
N
Y
COMPARE NEW DATA SET TO COMPOSITE DATA
78
MATCH ?
80
N
Y
CHECK NUMBER OF RETRIES (R)
90
INDICATE MATCH
96
R < THRESH ?
92
Y
N
STOP
98
INDICATE FAIL AND DENY ACCESS
94

FIG. 4.

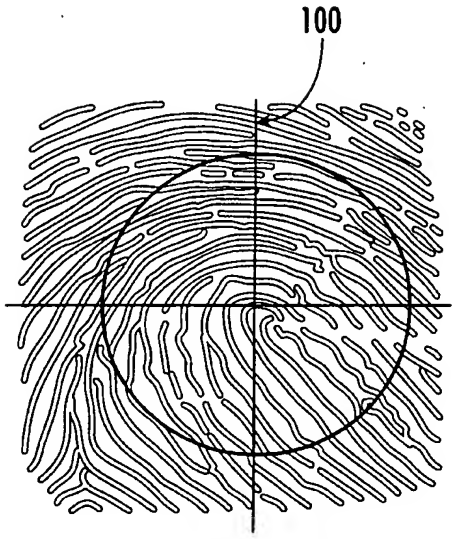

FIG. 5.

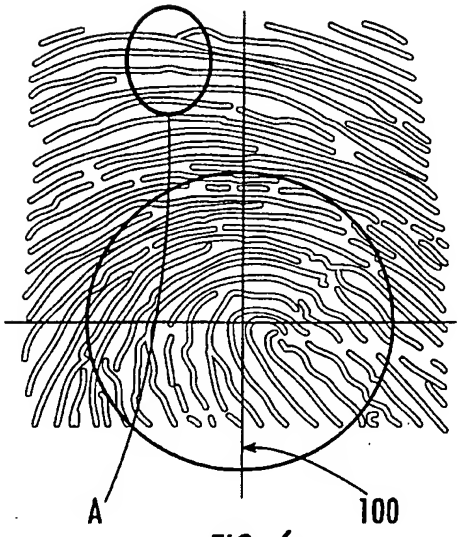

FIG. 6.

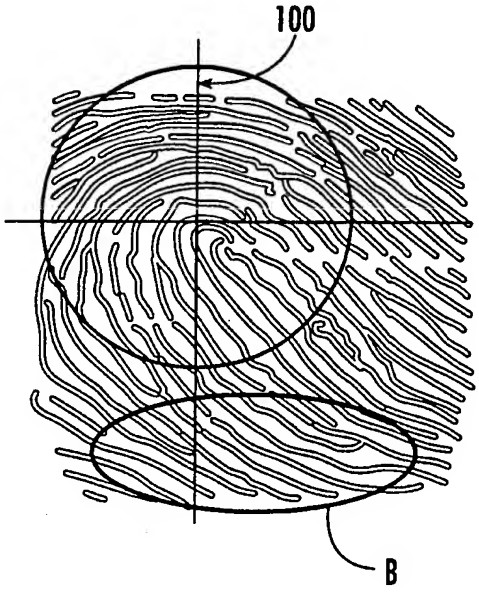

FIG. 7.

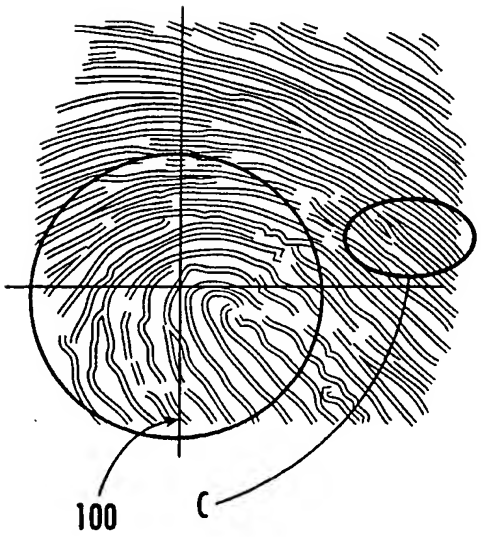

FIG. 8.

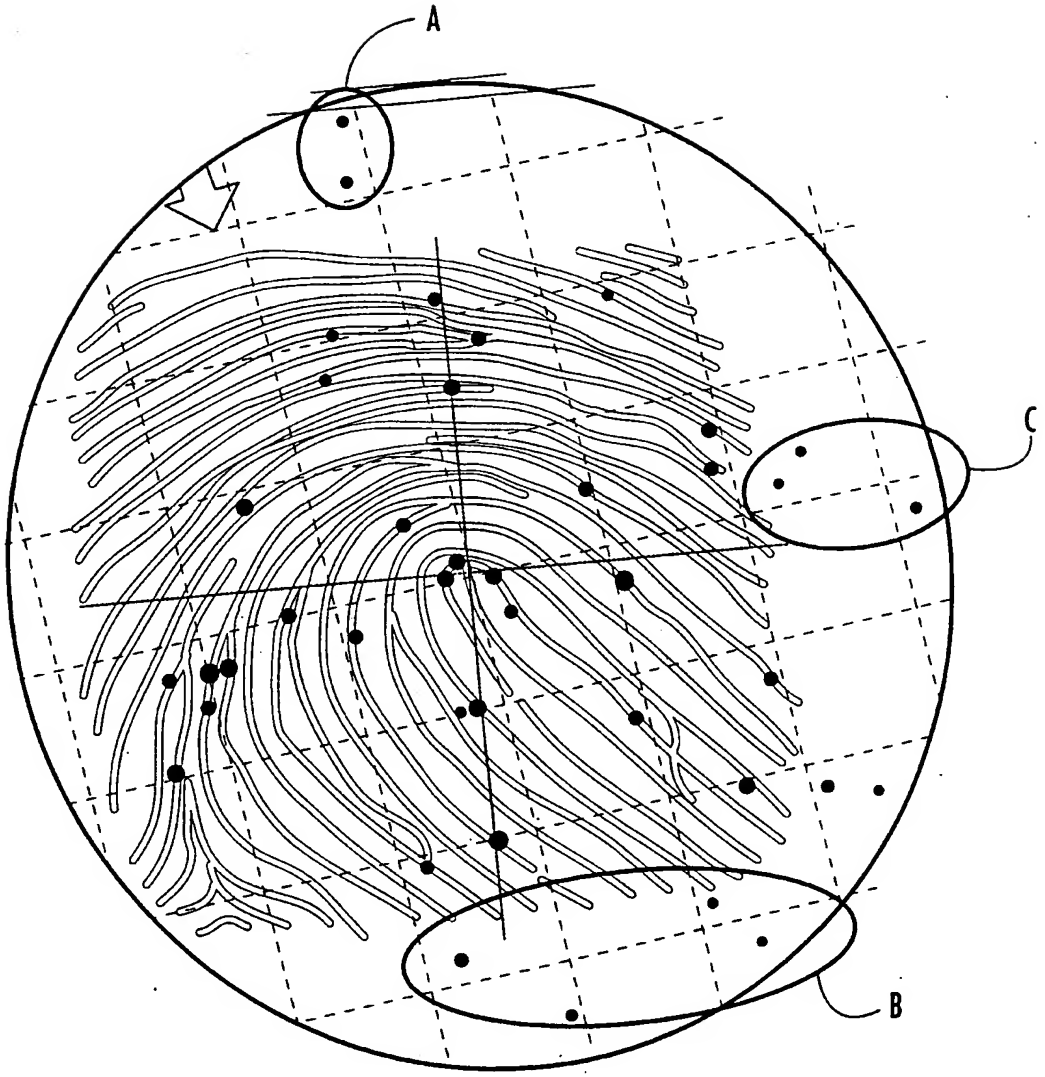

FIG. 9.

INTERNATIONAL SEARCH REPORT

Inte. ›nal Application No
PCT/US 00/12784

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06K9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 46114 A (ARETE ASSOCIATES) 22 October 1998 (1998-10-22) abstract page 29, line 17 - line 24 page 57, line 1 - line 7 page 21, line 8 - line 34 ---	1,8, 13-16, 27-30, 34-42, 46-51
X	EP 0 778 541 A (HAMAMATSU PHOTONICS KK) 11 June 1997 (1997-06-11) abstract --- -/--	1,12,14, 15,26, 28,40,41

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2000	05/09/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Inte onal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 99 06942 A (LEE JONATHAN A ;PARE DAVID F (US); SMARTTOUCH INC (US); LAPSLEY PH) 11 February 1999 (1999-02-11) abstract	4,18,33, 45

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INTERNATIONAL SEARCH REPORT

information on patent family members

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PCT/US 00/12784

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		CN 1249046 T	29-03-2000
		EP 0931294 A	28-07-1999
EP 0778541 A	11-06-1997	JP 9147115 A	06-06-1997
		DE 69608218 D	15-06-2000
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WO 9906942 A	11-02-1999	US 5982914 A	09-11-1999
		AU 8762998 A	22-02-1999